Evolution of a multi-centre knowledge-based treatment planning model for radiotherapy of cervical cancer

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# RapidPlan knowledge-based planning

- Based on library of clinical plans
  - Difficult to implement for
    - New sites/techniques
    - Rare indications
- Requires significant resources to set up model [1]
  - Building DVH Estimation model
  - Defining template of optimisation objectives
  - Dependent on experience of user

[1] Hussein et al. Clinical validation and benchmarking of knowledge-based IMRT and VMAT treatment planning in pelvic anatomy. Radiother. Onocol. 2016; 120; 473-9
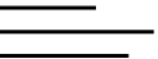
UK RapidPlan Consortium (UKRC)

- Founded 2017
  - Four UK centres, two with RapidPlan experience, two just starting with RapidPlan
  - Now expanded to nine centres
- Goals
  - Share expertise/experience
 - Evaluate potential for model-sharing between centres
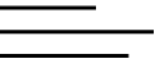
Initial model: cervical cancer

- Both centres 1 & 2 (C1 & C2) already had in-house models for cervix + nodes
  - VMAT, 45/50.4Gy in 1.8Gy/#
  - Included post-hysterectomy and intact uterus cases

- Model from C1 ($Model_{C1}$) was shared with C2 & C3, who tested a single optimisation against their own clinical plans
  - C2: used own RP model
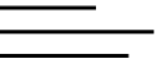 - C3: used template-based optimisation
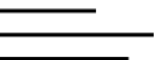
Results from initial testing

- C2 (own RP model); Model_C1 gave:
  - Improved FH doses
  - Reduced bladder/rectal volumes around 45Gy
  - Higher bladder/rectal mean doses
  - Reduced conformality of 95% isodose

- C3 (template-based); Model_C1 gave:
  - Higher PTV V105%
  - Less conformal low doses
  - Higher bladder doses
- C3 local tolerances for bladder tighter than for C1 or C2 at low doses
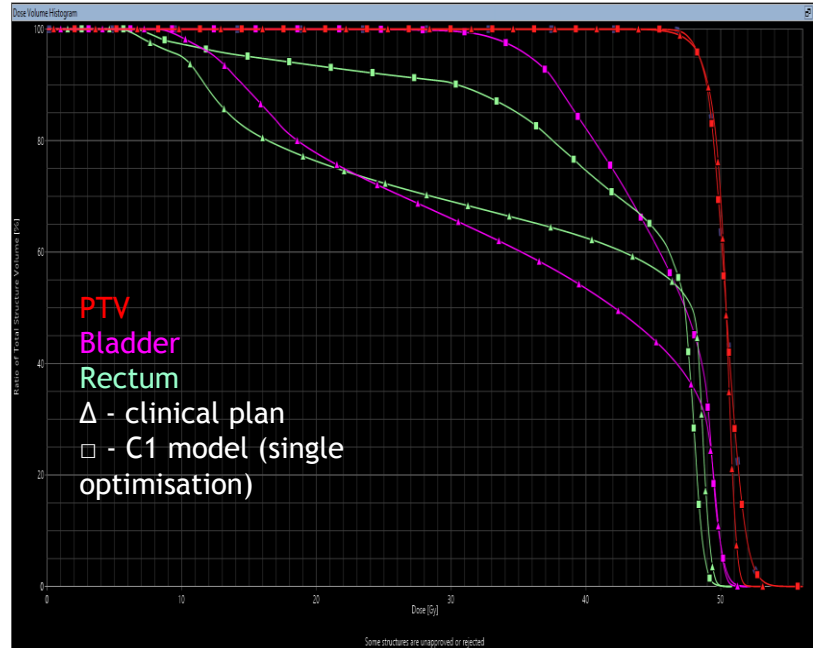
Modified models

- Alternative modified models created :
  - UKRC1 – combination of constraints from C1 and C2
    - Relaxed PTV objectives
    - Included additional objectives on OARs, especially at lower dose levels
    - Adjusted normal tissue objective (NTO)

  - UKRC2
    - Adjusted NTO

- Models tested by C1
  - 10 patients
  - Single optimisation without user interaction
  - Results compared to original C1 model

Modified model testing: OAR results

- Both modified models gave significant improvement in OAR sparing for bladder, rectum and bowel
- Little difference between UKRC1 and UKRC2

		Mean ± standard deviation			p-value		
		Model$_{C1}$	Model$_{UKRC1}$	Model$_{UKRC2}$	UKRC1 vs C1	UKRC2 vs C1	UKRC2 vs UKRC1
Bladder	D50% (Gy)	45.7 ± 3.1	45.2 ± 3.8	45.1 ± 3.9	-	0.01	-
	V50.4Gy (%)	0.6 ± 1.2	1.5 ± 2.1	0.8 ± 1.5	0.03	0.04	0.03
	V35Gy (%)	89.3 ± 11.3	82.4 ± 13.8	82.8 ± 13.9	0.01	0.01	-
	V40Gy (%)	76.2 ± 15.4	71.4 ± 16.1	72.0 ± 17.0	0.02	0.01	-
	V50Gy (%)	0.7 ± 1.1	1.6 ± 2.0	1.0 ± 1.6	0.01	0.04	0.04
Rectum	V30Gy (%)	61.6 ± 28.2	60.6 ± 27.4	60.8 ± 27.4	0.01	0.04	-
	V35Gy (%)	57.8 ± 24.8	56.3 ± 24.5	56.5 ± 24.2	0.01	0.04	-
	V45Gy (%)	42.3 ± 24.6	39.8 ± 23.7	41.2 ± 24.0	0.01	0.04	0.01
	D50% (Gy)	46.8 ± 2.1	45.4 ± 1.6	46.5 ± 2.3	-	0.05	-
	D60% (Gy)	45.4 ± 3.2	44.0 ± 2.9	44.9 ± 3.7	0.01	0.05	0.03
Bowel	D30% (Gy)	35.5 ± 10.9	33.3 ± 10.3	34.0 ± 10.7	0.01	0.01	0.07
	V15Gy (cm^3)	683 ± 291	690 ± 290	689 ± 292	-	0.01	-
	V25Gy (cm^3)	547 ± 262	513 ± 240	524 ± 249	0.02	0.06	0.09
	V45Gy (cm^3)	159 ± 84	146 ± 68	152 ± 77	0.05	0.04	-
	V50.4Gy (cm^3)	5.2 ± 8.5	9.6 ± 10.7	7.7 ± 12.0	0.01	0.01	0.09
Right femoral head	D15% (Gy)	32.1 ± 3.8	33.0 ± 3.1	32.4 ± 3.1	-	-	-
	D50% (Gy)	23.7 ± 2.9	26.0 ± 2.2	24.2 ± 1.7	0.01	-	0.02
	Dmax (Gy)	44.3 ± 3.5	44.7 ± 3.5	44.8 ± 3.4	-	-	-
Left femoral head	D15% (Gy)	35.2 ± 6.6	33.9 ± 3.8	32.7 ± 3.9	-	-	0.03
	D50% (Gy)	27.6 ± 8.3	26.5 ± 2.3	24.9 ± 2.1	0.09	-	0.01
	Dmax (Gy)	46.3 ± 3.9	45.7 ± 3.9	44.8 ± 4.0	-	-	-
Bone marrow	Dmean (Gy)	30.7 ± 2.2	29.7 ± 2.3	30.0 ± 2.1	0.01	0.005	0.07
	V10Gy (%)	91.9 ± 4.4	92.6 ± 4.5	92.4 ± 4.3	0.08	0.06	-
	V20Gy (%)	74.2 ± 5.3	75.8 ± 5.8	75.1 ± 5.0	0.01	0.03	-

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Modified model testing: OAR results

		Mean ± standard deviation			p-value		
		Model$_{C1}$	Model$_{UKRC1}$	Model$_{UKRC2}$	UKRC1 vs C1	UKRC2 vs C1	UKRC2 vs UKRC1
Bladder	V35Gy (%)	89.3 ± 11.3	82.4 ± 13.8	82.8 ± 13.9	0.01	0.01	-
	V40Gy (%)	76.2 ± 15.4	71.4 ± 16.1	72.0 ± 17.0	0.02	0.01	-
	V50Gy (%)	0.7 ± 1.1	1.6 ± 2.0	1.0 ± 1.6	0.01	0.04	0.04
Rectum	V30Gy (%)	61.6 ± 28.2	60.6 ± 27.4	60.8 ± 27.4	0.01	0.04	-
	V35Gy (%)	57.8 ± 24.8	56.3 ± 24.5	56.5 ± 24.2	0.01	0.04	-
	V45Gy (%)	42.3 ± 24.6	39.8 ± 23.7	41.2 ± 24.0	0.01	0.04	0.01

- UKRC2 shows small increase in high dose region for bladder/rectum but little clinical significance
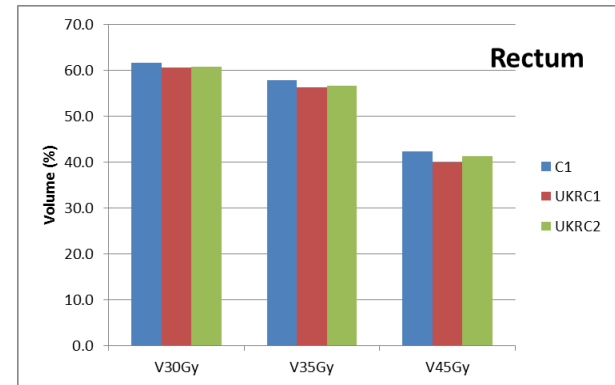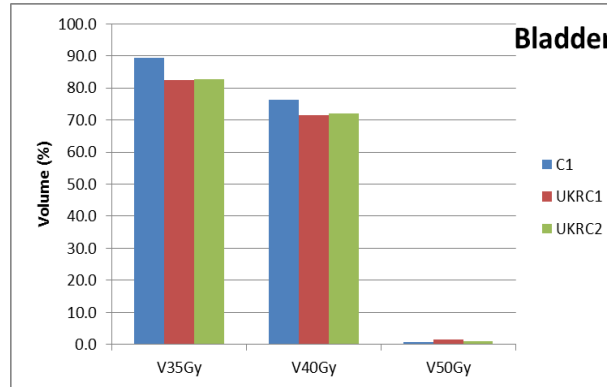
Model testing: PTV

- Both models showed a reduction in PTV coverage and homogeneity
  - UKRC1 considerably worse than C1
  - UKRC2 more comparable to C1
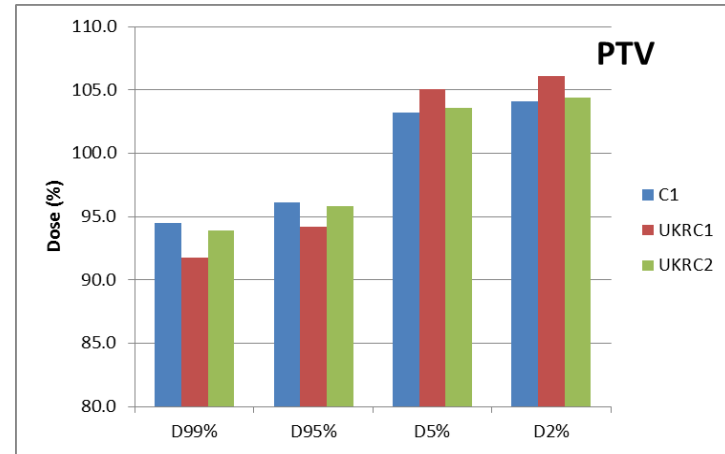
		Mean ± standard deviation			p-value		
		Model$_{C1}$	Model$_{UKRC1}$	Model$_{UKRC2}$	UKRC1 vs C1	UKRC2 vs C1	UKRC2 vs UKRC1
PTV	D99% (%)	94.5 ± 0.4	91.8 ± 0.3	93.9 ± 0.4	0.01	0.01	0.01
	D95% (%)	96.1 ± 0.3	94.2 ± 0.4	95.8 ± 0.3	0.01	0.005	0.01
	D5% (%)	103.2 ± 0.4	105.0 ± 0.5	103.6 ± 0.4	0.01	0.01	0.01
	D2% (%)	104.1 ± 0.6	106.1 ± 0.6	104.4 ± 0.5	0.01	0.01	0.01

UKRC2 final testing

- Centres 1, 2 and 3 all tested the UKRC2 model
  - 5 - 10 patients from each centre
    - Template-based optimisation
    - Single optimisation with UKRC2, no interaction
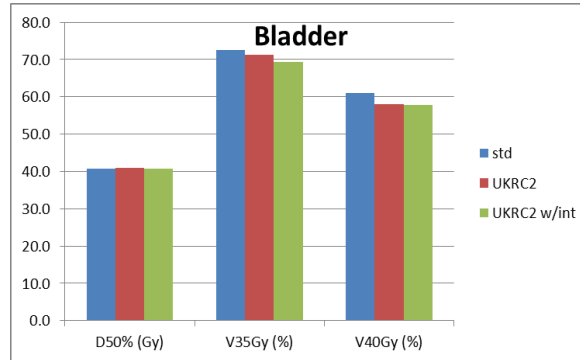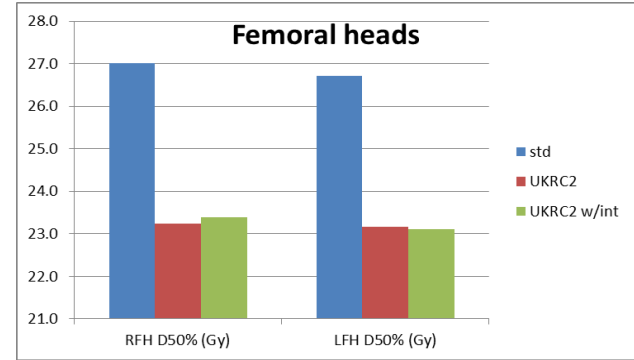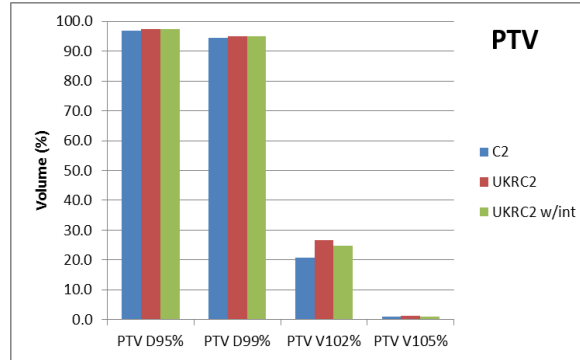   - UKRC2 with interaction & subsequent iterations
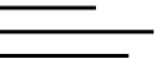
Centre 1

- Final plan from UKRC2 cf standard plan:
  - Improved PTV homogeneity
 - Reduced rectal and FH doses
  - Similar bladder doses
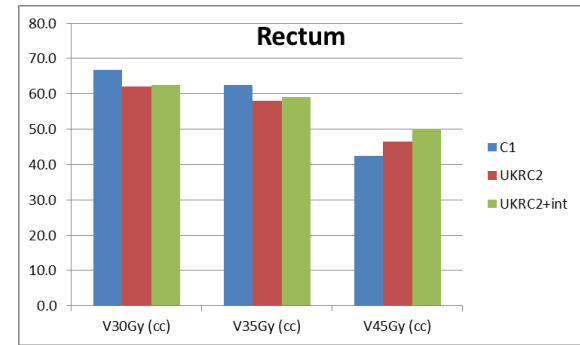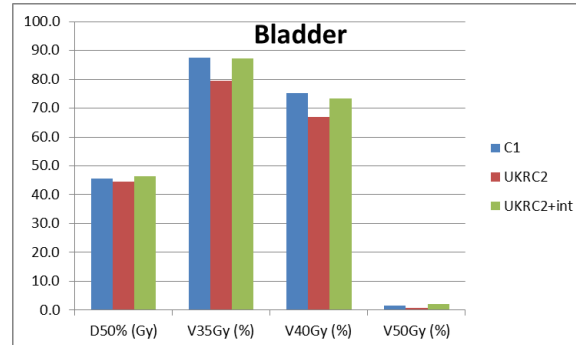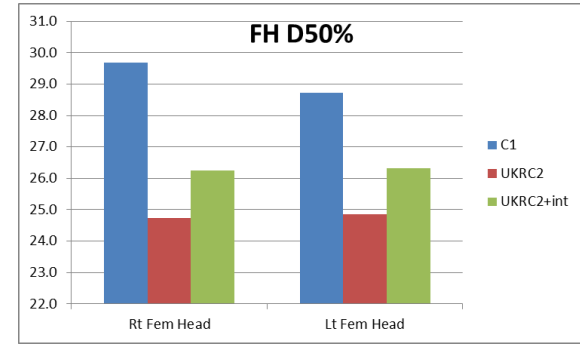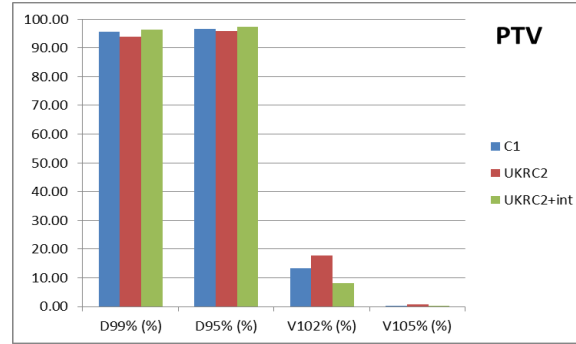
Centre 2

- Final plan from UKRC2 cf standard plan:
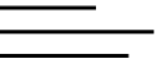 - Increase in PTV V102%
  - Reduced doses for all OARs
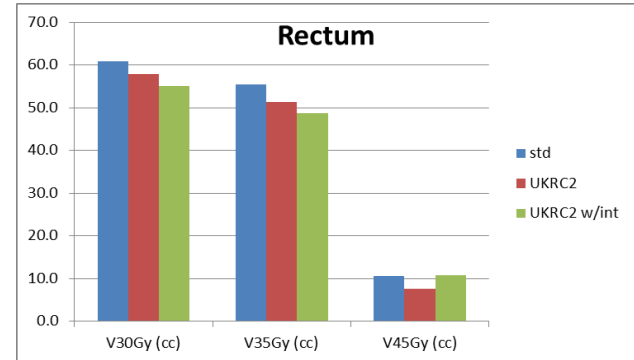
- Final plan from UKRC2 cf standard plan:
  - Increase in PTV V102%
  - Increase in low dose but reduction in high dose for bladder
  - Increased FH doses, but not clinically significant
  - Significant time savings compared to template-based optimisation
    - RP:50 ±10min
    - T: 250 ± 60min
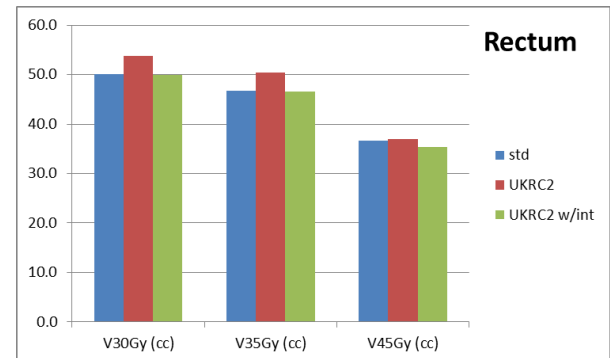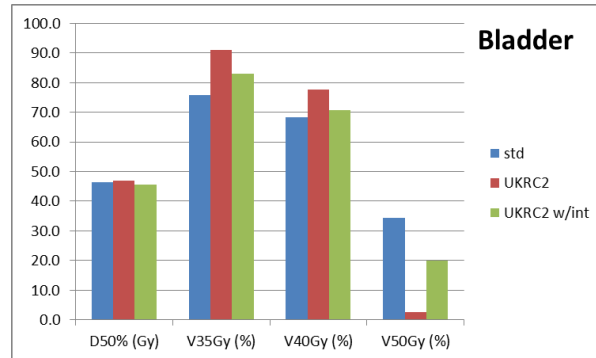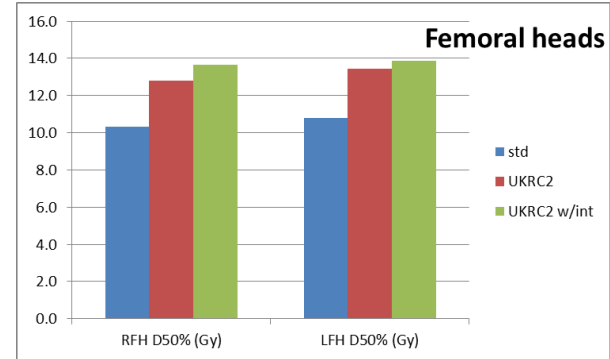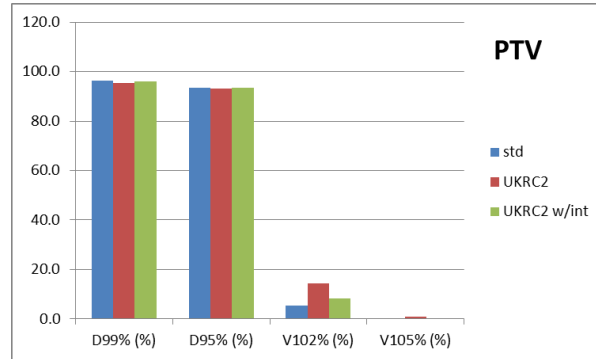
Conclusions

- Models can successfully be shared between centres
  - Can act as good starting point, even when model created with different acceptance criteria
  - Significant time savings possible without developing in-house model

- Combining expertise led to an improved model compared with individual centre models

Acknowledgements